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REVIEW

Tunnelled Catheters for the Haemodialysis Patient

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Haemodialysis depends upon the establishment of a durable means of vascular access. Although the creation of a successful arterio-venous Fistulae (AVF) is the ideal, this is not always possible or practical. Tunnelled catheters play an important role as an interim/bridge technique for emergency access or while an AVF matures, but may be associated with significant morbidity. The aim of this review is to highlight recent evidence based developments in tunnelled catheters, including methods of placement, complications and possible management strategies.

Keywords: Tunnelled catheters; Haemodialysis.

Introduction

The provision of permanent vascular access for haemodialysis (Table 1) presents an ever-increasing challenge to the surgeon. This is attributable to the rapidly expanding dialysis-dependent population,¹ an increase in the number of elderly and diabetic patients considered for renal replacement therapy and prolonged patient survival on dialysis.² The Kidney Disease Outcome and Quality Initiative (K/DOQI) practice guidelines define standards for dialysis access and maintenance.³ Autogenous vein arteriovenous fistulas (AVF) are the vascular access of choice in patients requiring long-term haemodialysis, as they are associated with superior long-term patency and low complication rates.^{4,5} These advantages are offset by high primary failure rates (11–30%)^{6,7} and the time taken for maturation (up to 4 months for radiocephalic fistulas). In view of this, arteriovenous grafts have gained favour with some because of their superior short-term results, with low rates of primary failure⁸ and the fact they can be used immediately for haemodialysis if necessary. They are, however, also associated with inferior patency and higher complication rates leading to increased overall morbidity and escalating hospital costs in the long-term.⁹

The widespread use of autogenous vein AVFs can be successfully achieved by the use of tunnelled cuffed haemodialysis catheters as an interim/bridge access whilst autogenous AVFs mature. Their use is however associated with significant morbidity, poor patency (Table 1) and frequent hospitalisation which limits their usefulness.^{10–12} Hence a clear understanding of catheter management and their complications is essential for the success of a vascular access programme. Various strategies to minimise tunnelled haemodialysis catheters use are also of utmost importance and should take into consideration; patient modality presentation, peritoneal dialysis, vascular access counselling with pre-operative mapping, salvage of early access failure and thrombosed fistulae.¹³ The purpose of this review is to highlight recent evidence-based developments in (1) methods of placement and (2) management of catheter-related complications which may improve long-term catheter function and ultimately promote the more widespread use of the autogenous vein AVFs rather than arteriovenous grafts.

For practical purposes the review has been divided into 1. tunnelled catheters, 2. placement of catheters, 3. procedure, 4. complications.

Methods

For this review a detailed Pubmed and Ovid search was performed looking for haemodialysis catheters,

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Table 1. Use of the tunnelled haemodialysis catheter

Maturation of autogenous AVF
 Maturation of Continuous Ambulatory Peritoneal Dialysis (CAPD)
 Awaiting living-related transplantation
 'Dialysis Bridge' following failed previous vascular access/CAPD
 allowing planning and imaging for 'long-term' access
 Permanent access- all other sites exhausted/severe cardiac
 dysfunction/vascular arterial disease

long term tunnelled dialysis catheters as well as central venous catheters.

The ovid search was used to evaluate references where firm recommendations are made, based on solid evidence such as randomised controlled trials and K/DOQI clinical practice guidelines.^{3,7,14} Since evidence based medicine also uses the best available evidence, this review dose not exclude recommendations based from non randomised trials.^{12,13,15}

Tunnelled catheters

The tunnelled catheters for dialysis can be either cuffed or uncuffed and tunnelled either antegrade (skin to insertion site) or retrograde (insertion site to skin). Cuffed tunnelled haemodialysis catheters have a number of advantages over non-cuffed non-tunnelled catheters. Modern cuffed tunnelled catheters are made of silicone or polyurethane. Silicone is thermoset and thus the catheter is soft, whilst polyurethane is thermoplastic and softens at body temperature. This reduces endothelial damage and thrombogenicity.¹⁵ Incorporation of the cuff into surrounding tissue and the formation of a subcutaneous tunnel are thought to provide physical barriers to infection.¹⁶ Other features of catheter design such as larger lumens and the separation of inlet and outlet ports serve to reduce low flow and recirculation. Designs vary widely between different types of catheter. Dual lumen catheters are the most commonly used, although twin single lumen catheters provide an alternative. In a prospective randomised study of 64 patients comparing mean blood flow, reliability (Table 2), and recirculation of these three types of haemodialysis catheter, the mean blood flows were PermCath™ 383.6 ml/min, Tesio™ 396.3 ml/min and VasCath™ 320.4 ml/min. Reliability of catheters was PermCath 86.9%, Tesio 81.6% and VasCath 42.3%.¹⁷ Permcath and Tesio had significantly higher blood flows and reliability than VasCath catheters ($P < 0.005$), whilst recirculation rates were comparable: PermCath 3.7%, Tesio 3.9% and VasCath 4%. Whilst there were clear differences between these catheters, all three catheters proved inferior to the

Table 2. Definitions of catheter function

1. Patency; length of time that a catheter provides adequate extracorporeal flow for effective haemodialysis (in practice >300 mL/min)
2. Primary Patency; cumulative catheter patency until the first therapeutic intervention required to maintain patency
3. Secondary Patency; cumulative patency from catheter placement to failure regardless of the number of therapeutic interventions required to maintain patency
4. Reliability; defined as the percentage of treatments performed at a median blood flow of 350 ml/m or above
5. Catheter dysfunction; defined by the DOQI as failure to attain and maintain an extra corporeal blood flow sufficient to perform haemodialysis, without significantly lengthening the dialysis treatment

control arteriovenous fistula group: mean blood flow 437 ml/min, reliability 96% and standardised kinetic urea clearance (Kt/V) 1.64 (versus PermCath 1.42, Tesio 1.44 and VasCath 1.19; $P < 0.005$), thus necessitating longer dialysis times.

Despite modifications in catheter design, catheter thrombosis and catheter-related sepsis remain the major complications limiting their long-term use.^{12,14} Catheter-related bacteraemia rates for non-tunnelled non-cuffed haemodialysis catheters range from 0.16–0.86 per 100 days,¹⁸ whereas those for tunnelled cuffed catheters range from 0.016–0.29 per 100 days.^{19,20} No prospective randomised trials comparing infection related morbidity in haemodialysis catheters have been reported in the literature. Two prospective randomised studies in non-haemodialysis central venous catheters suggest equivocal evidence that tunnelled cuffed catheters have lower infection rates.^{16,21} Andrivet *et al.* demonstrated a reduction in catheter-related sepsis with cuffed tunnelled catheters in immunocompromised patients, although this failed to reach statistical significance (2% vs 5%), whilst Timsit *et al.* showed a significant reduction in catheter-related sepsis in patients who received a tunnelled internal jugular catheter following admission to the intensive care unit ($P < 0.02$).

Secondary patency rates for tunnelled catheters vary widely ranging from 25% to 75% at one year^{22,23} (Table 2). This is unlikely to be solely due to catheter design, but decreased catheter patency is more likely to represent failings in aseptic technique and general catheter care²⁴ and the correct management of catheter dysfunction and treatment of infection.

Catheter placement

The advantages of these catheters are their ease of insertion, the ability to insert them in multiple sites

in almost any patient and the lack of haemodynamic compromise associated with their use. Vascular access diagnosis is of utmost importance and all patients should undergo duplex ultrasonography to delineate the most suitable vein, though it may be done right at the time of the procedure. Similarly patients who have undergone various vascular access procedures, importance must be given to flebography to rule out central venous stenosis or occlusion and map veins that cannot be mapped by ultrasonography. The subclavian approach gained popularity in the 1960s and early 1970s, providing convenient positioning and allowing patient ambulation in contrast to the femoral approach of non-tunnelled catheters. However, it soon became clear there was a price to pay for such convenience. Subclavian vein cannulation is associated with an incidence of 42–50% stenoses as detected by venography.^{12,15,16}

Schwab *et al.* evaluated 47 patients with fistula dysfunction using upper arm venography. Subclavian vein stenosis was documented in 12 patients, all of whom had undergone previous subclavian vein catheterisation. This study highlights two further important points. Firstly, subclavian stenosis may be clinically asymptomatic until an arteriovenous fistula is fashioned in the ipsilateral arm. Second, central venous stenosis accounts for 40% of venous stenoses associated with AVFs. It is therefore paramount that long-term access options are preserved at all costs when providing acute vascular access for haemodialysis. It is for this reason that the subclavian vein catheterisation is now discouraged (K/DOQI), except as a last resort.^{25,26}

The preferred site for catheter insertion is the right internal jugular vein as anatomically this provides the most direct route to the superior vena cava and right atrium, and is associated with better patency and fewer complications than other sites.²⁷ Insertion into the left internal jugular vein is associated with increased incidence of central stenosis and poorer patency.^{28,29} To date, there are no randomised prospective trials comparing the incidence of complications between these two routes. In selected subgroups, in which all other routes have been exhausted, tunnelled catheters can be placed into the external iliac vein, the femoral vein³⁰ and even the inferior vena cava via a transhepatic³¹ or translumbar approach.³²

Procedure

Tunnelled catheters have traditionally been inserted by surgeons in theatres via a cut down method.

However, interventional radiologists and nephrologists are increasingly siting them by percutaneous techniques in the radiology department or treatment rooms. Ultrasound guided internal jugular vein cannulation has resulted in significantly increased first time and successful cannulation in patients whom conventional percutaneous techniques have failed.³³ Whilst results from percutaneous techniques are encouraging and appear comparable to surgical insertion,³⁴ there are no prospective randomised trials comparing open and percutaneous techniques.

In both surgical and percutaneous procedures, the catheter is tunnelled subcutaneously for a distance of 10 cm from the vein entry site to reduce systemic sepsis. It is important to keep simple practical facts in mind such as uncuffed catheters are stiffer than cuffed catheters and thus ideally selected as per vein to be cannulated, in addition to length of time they are left in a particular vein.

The catheter should be placed under fluoroscopic control³⁵ with its tip in the superior vena cava,³ although some authors report improved patency with the tip in the atrium.³⁶ Deitel *et al.* reported a malposition rate of 29% in the absence of radiological guidance.³⁷ Atrial perforation and catheter-induced arrhythmias have been reported, but are less likely to occur with softer silicone tunnelled catheters. Atrial placement minimises recirculation³⁸ and also catheter migration associated with changes in posture. Studies have shown significant catheter tip migration of several centimetres when the patient assumes the erect from the supine position.^{39,40} Thus in the atrio-caval position, optimal flow may not be obtained once patient is erect and this needs to be factored into the initial catheter tip placement. During the tunnelling process the lumen can be very easily compromised by kinks^{12,41} which are best avoided by the creation of a smooth arc in the tunnel using a tunneler bent into a 'C' or 'U' shape.⁴² The procedure must always be followed by a simple chest radiograph as it can quite easily exclude the possibility of kinking and catheter malpositioning due to catheter tip migration.

Complications

These can be further divided into (A) Immediate/Short-term and (B) Long-term. Catheter dysfunction is a common complication in relation to both, but with different etiological factors.

A) Immediate/Short-term (Table 3)

These are all related to the insertion process and are familiar to most doctors dealing with dialysis catheter

Table 3. Short-term complications

Arterial Puncture and central vessel perforation
Bleeding
Pneumothorax
Haemothorax
Haemomediastinum
Atrial Perforation
Dissection/occlusion of carotid artery
Air embolus
Arrhythmias
Primary failure- technical error

insertion. The main factor in management of these complications is awareness and prevention.^{42,43} Ultra-sound guidance has markedly reduced these complications,³ in addition to meticulous practice. The use of a 21-gauge micropuncture set and gradual dilators over a 0.035 mm guide wire further reduces them avoiding the need to puncture the vessel with an 18-gauge needle.⁴²

B) Long-term (Table 4)

Catheter dysfunction (Table 2)

Catheter dysfunction occurs when adequate extra corporeal flow of 300 ml/min cannot be achieved and maintained (DOQI). It accounts for 17–33% of catheter removals.^{31,44} Early catheter dysfunction in the postoperative period is due to technical errors in catheter placement. Common problems include kinking of the catheter in the subcutaneous tunnel and mal-positioning, the management of which was dealt with earlier under the heading procedure.

Later dysfunction is due primarily to catheter thrombosis, fibrin sheath formation or central vein thrombosis.^{45,46} Other less obvious causes for catheter dysfunction are catheter migration or vascular underfilling.⁴¹

Catheter lumen thrombosis

The reported incidence of catheter lumen thrombosis is as high as 46% and accounts for the majority of catheter dysfunctions.^{34,38} The K/DOQI recommend intracatheter instillation of a fibrinolytic agent such as urokinase

Table 4. Long-term complications

Catheter thrombus formation
Central Thrombus formation
Fibrin sheath formation
Central vessel stenosis
Catheter related infection
Permanent vascular ingrowth

(5000 IU/mL) as the primary management of catheter dysfunction. This volume must be adjusted depending on catheter specification hence sufficient to fill the internal lumen of the catheter and results in successful restoration of function in 70–90% of cases.^{34,47} Should this treatment fail, higher doses of 40,000 IU/mL for prolonged periods of up to 6 hours may be attempted.⁴⁸ Shrivastava *et al.* salvaged 21 catheters using mechanical deobstruction with a guidewire in 24 patients in whom urokinase instillation had previously failed.⁴⁹ In literature tissue plasminogen activator (t-PA) has also been successfully applied, where a double blinded randomized trial showed a novel dose of 2 mg restored catheter function more reliably and dissolved thrombi faster than twice the standard FDA- approved dose of UK with 2 hours of incubation compared to urokinase.⁵⁰ If the fibrinolysis infusion fails and catheter migration or patient dehydration have been excluded, the presence of mural thrombus in the SVC or the presence of a fibrin sheath should be suspected.

More recently attention has focused on the prevention of thrombotic complications in these catheters. Trials of heparin bonding and low dose anticoagulant therapy are awaited and low catheter thrombosis rates have been reported in patients on low dose aspirin and warfarin therapy.¹⁴ In a randomised controlled trial of low dose warfarin (1 mg/day) in cancer patients with central catheters for chemotherapy, subtherapeutic anticoagulation reduced thrombotic complications from 38% to 10%.⁵¹ This is an important finding and should be translated to a haemodialysis programme, where a randomised controlled trial using low dose warfarin seems an appropriate next step.

Central thrombus formation

Mural thrombus in the SVC and the right atrial wall can be detected on transoesophageal echo in 30% of patients with central catheters⁵² and is often asymptomatic, although in some cases it can present with arm and facial oedema. Central vein thrombosis can be identified by MR or conventional venography. Treatment by infusion of a fibrinolytic agent produces good results however angioplasty and stenting may be required for organised thrombus.⁵³ There are no studies reported in the use of anticoagulation to prevent pulmonary emboli and clot propagation.

Fibrin sheaths

Injection of contrast through the catheter ports under fluoroscopic screening, (a “permacathogram”) may show features suggestive of a fibrin sheath such as

a persistent filling defect at the catheter tip or reflux of the contrast retrogradely along the sheath.⁵⁴ Fibrin sheaths account for 13–57% of catheter dysfunction⁵⁵ but may represent a ubiquitous response to indwelling catheters, as they are present in 100% of patients with central catheters at post mortem.⁵⁶ They can be short or long and seem to originate from the site of insertion or the cuff and tend to migrate down the length of the catheter covering the inflow and outflow holes resulting to dysfunction. If this is not recognized, an exchange procedure will result in no flow improvement as the catheter lies in the same existing sheath.⁵⁷ Fibrin sheaths may be treated by prolonged infusion of fibrinolytic agents (6 hours), mechanical stripping using a snare inserted via the femoral vein or by exchange of a catheter over a guidewire.^{47,48,58} Over night instillation of lytic enzymes has also been described.⁴² There is no clear indication which of these therapies is superior.³ Fibrin sheath stripping is reportedly successful at restoring function in 92%–98% of cases with acceptable primary patency (Table 2) (28% at 6 months) in some centers.⁴⁷ Other published short-term results of this procedure are very poor, however, with catheter dysfunction returning in a majority of patients by the fifth dialysis session after initial stripping.^{47,59} Alternatively the results of catheter exchange over a guide wire after disruption of the sheath with a balloon catheter are also acceptable with 93% restoration of function and 37% patency at 6 months.⁶⁰

Central vein stenosis

The incidence of central vessel stenosis is considerable. But this can be reduced by careful vein selection as discussed in the section on catheter placement. The management of central stenosis is evolving and catheter placement should be avoided on the same side of a planned or developing fistulae or graft. When ever found, endovascular balloon angioplasty should be attempted to a minimum of the contiguous uninvolved vein.⁶¹ Central vessel stenosis unfortunately tends to be recurrent.^{61–63} The use of flexible stents is gaining popularity, although the long term outcome is not clearly defined.^{64,65}

Catheter related infection (CRI)

Catheter infection is responsible for the failure of 6%–28% of catheters^{12,14,18} and therefore represents a major cause of catheter morbidity and mortality. Diagnosis of CRI is based on criteria defined by the centre for disease control (CDC).⁶⁶ It requires at least

one of the following: (1) clinical exit site infection with evidence of inflammation within 2 cm of exit site; (2) definite blood stream infection, isolated plausible significant organism from catheter and peripheral blood, with no apparent source of infection; (3) probable blood stream infection with defervescence after catheter removal where both blood and catheter tip infection is not confirmed in a symptomatic patient with no apparent source of infection; (4) possible bloodstream infection in a symptomatic patient with defervescence after catheter removal, but remain culture negative.

The causative organisms are predominantly gram positive (52.5%), gram negative bacilli (26.7%) or polymicrobial (20.9%).^{15,67} Infection occurs most commonly by migration of skin organisms along the external surface of the catheter from the exit site wound or via the lumen of the catheter due to breakdown in aseptic technique by health care staff.³⁵ The organisms are usually embedded in a biofilm layer that confers protection from antibiotic therapy^{68,69} and there is a link between the number of organisms retrieved by culture from a catheter surface and the risk of systemic sepsis. Infection occurs when the organisms on the catheter exceed a certain quantitative threshold.³¹ Reported rates of exit site infections and catheter related bacteraemia range from 1.2%–4.7% and 2%–5.5% per 1000 catheter days respectively.^{12,14,18,70,71} In most cases (90%)^{12,14,18,71} exit site infections respond to oral antibiotics without necessitating catheter removal. K/DOQI guidelines recommend the use of oral antibiotics for minor infections and intravenous if there is a discharge from the tunnel or exit site and there are no signs of systemic sepsis or positive blood cultures. If the infection fails to resolve using these measures only then should the catheter be removed and reinserted through a different track.³ Systemic sepsis or bacteraemia is associated with a much higher rate of catheter removal, with conservative measures only successful in treating the infection 20%–25%.^{14,18} Catheter associated sepsis has considerable morbidity with 22% of patients in a recent study developing severe complications such as osteomyelitis, arthritis, endocarditis, epidural abscess and death.^{67,70,72,73} K/DOQI guidelines recommend rapid removal of catheters in unstable patients with bacteraemia or in stable patients if the patient remains symptomatic 36 hours after achieving bactericidal levels of antibiotic in the serum. Several reports suggest that in stable asymptomatic patients without tunnel exit site infection, exchange of the catheter over a guidewire through the same tunnel is associated with freedom from recurrence of infection.^{69–71,74} The K/DOQI recommended that

parenteral antibiotics should be continued for 3 weeks in such cases although the evidence to support this is sparse. Preventative strategies aimed at reducing the rates of catheter infection include the handling of dialysis catheters only by specially trained staff, the use of dry gauze dressings at the exit site and the use of antibiotic coated catheters. Although antibiotic coated catheters have been shown to reduce the incidence of line sepsis in intensive care patients^{75–77} the antibiotic tends to be washed off with time and therefore may not be beneficial in catheters used for intermediate or long term dialysis. Other recommendations such as the routine application of topical antibiotic to the exit site to reduce levels are unproven and may in fact encourage colonisation with fungi or multi-resistant organisms.

Permanent vascular ingrowth

Tissue in-growth into the catheter is a potentially serious complication as it entraps the catheter onto the endothelial surface of the vessel.⁴² There is no defined management for this problem. Surgical management would require a thoracotomy as cut down on to the internal jugular vein for catheter removal is not possible.

Conclusion

An understanding the principles of catheter related placement, complications and their management is essential to the success of a vascular access programme. Overall, and despite their disadvantages, cuffed tunnelled catheters can provide long-term salvage access in a small minority of patients in whom all other alternatives have been exhausted. For the vast majority of patients however, their low patency rates and high incidences of infective and thrombotic complications mean that their use should be restricted to medium-term temporary access whilst a definitive access is planned or is maturing. The poor patency rates can be improved by the implementation of strategies designed to prevent and treat the possible complications. Furthermore, inappropriate use of these catheters can have deleterious consequences in reducing long-term dialysis sites.

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